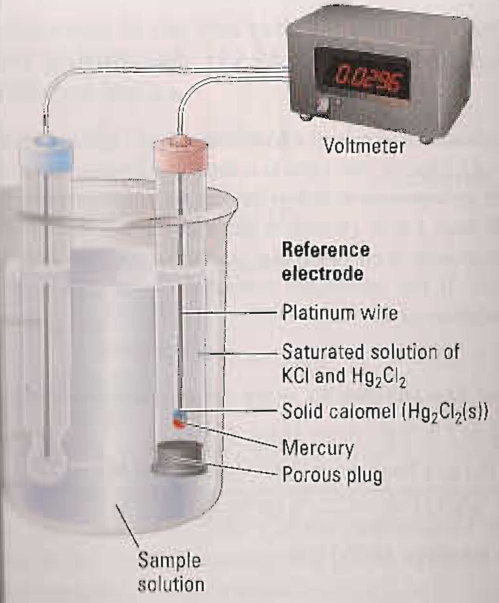


[illegible] **[illegible] of the pH meter.** The glass electrode is a [illegible] [illegible] is enclosed by a glass membrane. It is sensitive to the [illegible] [illegible] in the internal standard HCl solution. The saturated [illegible]

ells

[illegible] specialized cells called **neurons** that [illegible] [illegible] signals generated by changes in the [illegible] [illegible] (Figure 19.13). The [illegible] [illegible] signals generated by millisecond-long [illegible] [illegible] in ion concentration. These electrical [illegible] [illegible] the neuron separating different [illegible] [illegible] while it is at rest—that is, while no signals [illegible] [illegible] These different resting ion [illegible] [illegible] that move ions across the cell [illegible] Na^+, K^+, Cl^-, and Ca^{2+}. The intracellular [illegible] [illegible] markedly from the extracellular [illegible]

[illegible] (mM)	Extracellular Concentration (mM)	Potentials (mV)
	150	+56
	3	−102

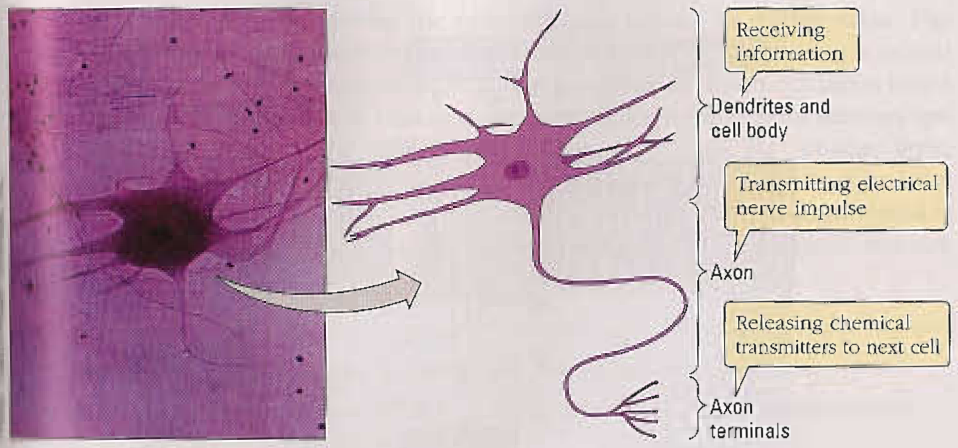


Figure 19.13 **A mammalian neuron cell.**

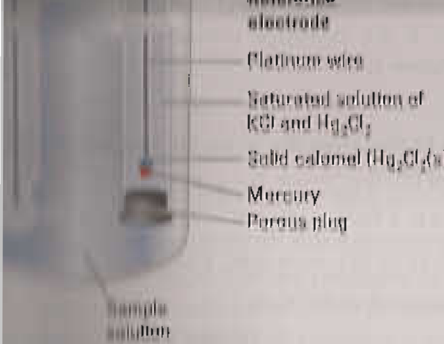
Substituting numerical values for the constants, R and F, assuming $n = 1$ and a body temperature of 37 °C, and converting to millivolts, we can simplify this expression to

$$E_{\text{ion}} = (61.5\text{ mV})\log\frac{(\text{conc. ion})_{\text{outside}}}{(\text{conc. ion})_{\text{inside}}} \qquad \text{(in mV)}$$

This expression computes the potential outside the cell membrane relative to the potential inside the cell membrane for each individual ion. Applying the equation to the specific case of K^+, we have $(\text{conc. }K^+)_{\text{outside}} = 3$ mM and $(\text{conc. }K^+)_{\text{inside}} = 135$ mM, so

$$\begin{aligned} E_{K^+} &= (61.5\text{ mV})\log\left(\frac{(\text{conc. }K^+)_{\text{outside}}}{(\text{conc. }K^+)_{\text{inside}}}\right) \\ &= (61.5\text{ mV})\log\left(\frac{3}{135}\right)\text{mV} = 61.5\,(-1.65)\text{ mV} = -102\text{ mV} \end{aligned}$$

The cell membrane has a potential that is 102 mV (0.102 V) more negative on the inside than the outside due to the much higher K^+ concentration inside the cell (Figure 19.15).



...ponents of the pH meter. The glass electrode is a Ag/AgCl ... enclosed by a glass membrane. It is sensitive to the external ... the internal standard HCl solution. The saturated calomel ele...

...lls

...specialized cells called **neurons** that commu... chemical signals generated by changes in the intra... concentrations (Figure 19.13). The communication ... electrical signals generated by millisecond-long alter... in ion concentration. These electrical signals ... of the neuron separating different concentrations of ... while it is at rest—that is, while no signals are being ... These different resting ion concentrations are ... that move ions across the cell membrane. The ... K^+, Cl^-, and Ca^{2+}. The intracellular concentra... markedly from the extracellular concentrations in

Extracellular Concentration (mM)	Potentials (mV)
150	+56
3	−102
120	−76
1.2	+125

...create potentials across the neuron cell ... potential for each ion is given by the Nernst

$$\frac{RT}{nF}\log\frac{(\text{conc. ion})_{\text{outside}}}{(\text{conc. ion})_{\text{inside}}}$$

Figure 19.13 A mammalian neuron cell.

Substituting numerical values for the constants, R and F, assuming $n = 1$ and a body temperature of 37 °C, and converting to millivolts, we can simplify this expression to

$$E_{\text{ion}} = (61.5\ \text{mV})\log\frac{(\text{conc. ion})_{\text{outside}}}{(\text{conc. ion})_{\text{inside}}} \qquad \text{(in mV)}$$

This expression computes the potential outside the cell membrane relative to the potential inside the cell membrane for each individual ion. Applying the equation to the specific case of K^+, we have $(\text{conc. K}^+)_{\text{outside}} = 3$ mM and $(\text{conc. K}^+)_{\text{inside}} = 135$ mM, so

$$E_{K^+} = (61.5\ \text{mV})\log\left(\frac{(\text{conc. K}^+)_{\text{outside}}}{(\text{conc. K}^+)_{\text{inside}}}\right)$$
$$= (61.5\ \text{mV})\log\left(\frac{3}{135}\right)\text{mV} = 61.5\,(-1.65)\ \text{mV} = -102\ \text{mV}$$

The cell membrane has a potential that is 102 mV (0.102 V) more negative on the inside than the outside due to the much higher K^+ concentration inside the cell (Figure 19.15).

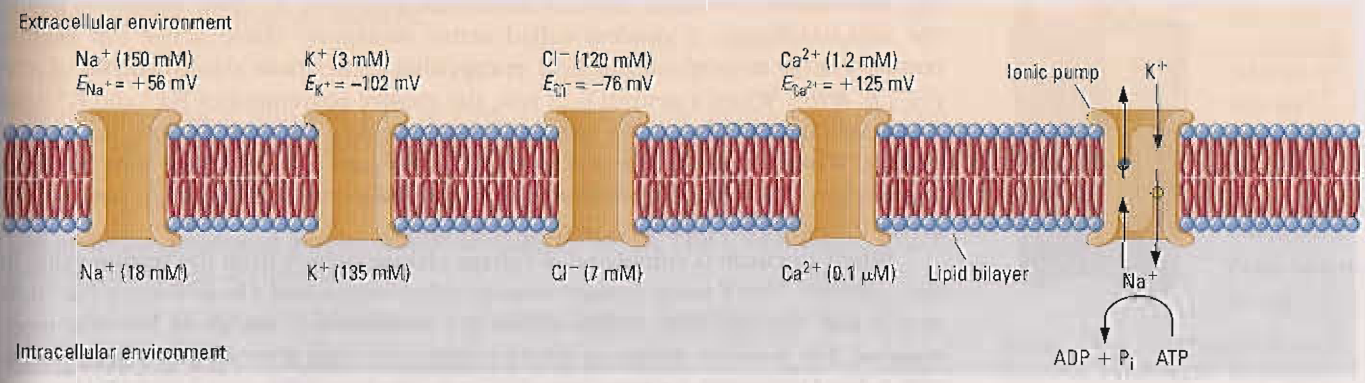


Figure 19.14 **Ion concentrations inside and outside a mammalian neuron cell.** Ion channels for Na^+, K^+, Cl^-, and Ca^{2+} are shown, as is the Na^+-K^+ ion pump. Concentrations are given in millimoles per liter, except for intracellular Ca^{2+}, which is given in micromoles per liter.

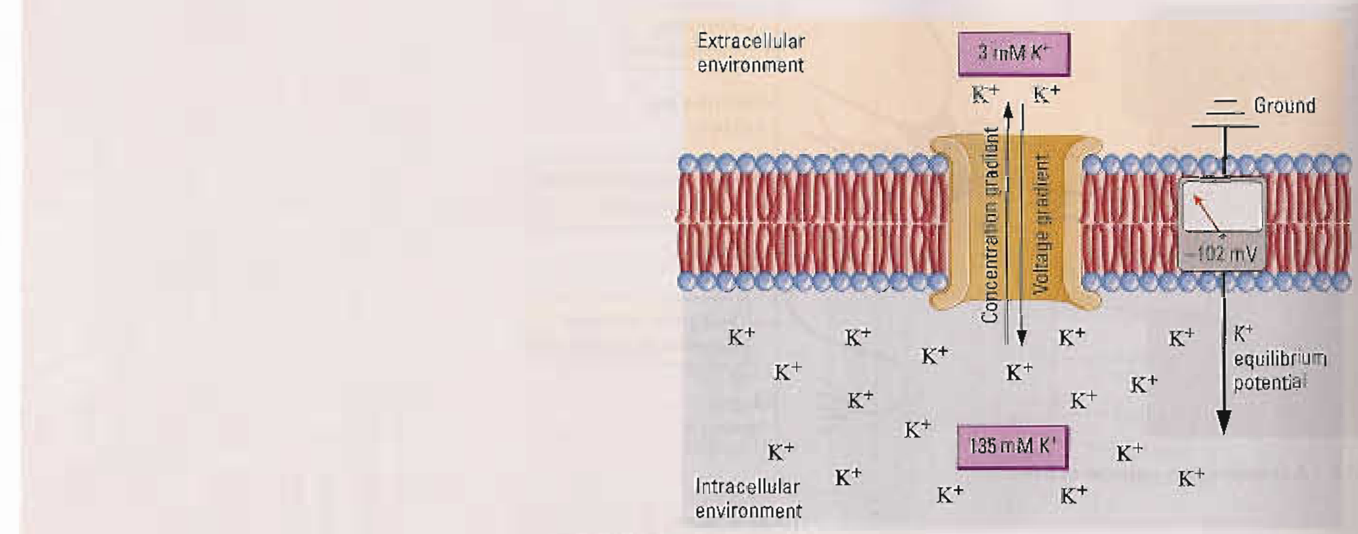


Figure 19.15 **The equilibrium potential for K^+ across a neuron cell membrane.** The K^+ concentration is higher inside the cell than outside it. The Nernst equation explains the −102 mV equilibrium potential for K^+.

Just as for K^+, each important ion shown in Figure 19.14 has a potential that depends on the concentrations of that ion inside and outside the cell membrane. The values for Na^+, K^+, Cl^-, and Ca^{2+} shown in the figure can be used with the Nernst equation to calculate the contribution that each ionic species makes to the final resting potential of the neuron. The *resting membrane potential* for a cell—that is, the potential when no nerve impulse is being transmitted—depends on each of the individual ion potentials. The equilibrium potentials for each of the ions involved are averaged in proportion to the relative permeability of the cell membrane for each ion. The resting membrane potential is different for different types of neuron cells and is in the range of −60 to −75 mV, with the inside of the cell being more negative than the outside.

How do the concentrations of ions inside and outside the cell membrane become different? Ions move across the cell membrane by several mechanisms, but all the ions undergo continual movement. In general, ions tend to move down concentration gradients, that is, from a region of higher to lower concentration. In addition, active *ion pumps* move Na^+ and K^+ *against* their concentration gradients, that is, from regions of lower to higher concentration. Thus, the ion pumps move Na^+ from inside to outside the cell membrane and move K^+ from outside to inside the cell membrane, a process called active transport. These active ion pumps require energy to perform this task, energy that comes from the hydrolysis of ATP (*p. 898*). When a neuron is at rest, the passive movement of Na^+ and K^+ ions is exactly counterbalanced by the active movement of Na^+ and K^+ ions via the ion

flow of K^+ out of the cell, [illegible] sequence leading to the [illegible] of about 1 ms (1×10^{-3} s). [illegible] the basis for the transmission of [illegible] tem. During this process, the [illegible] either inside or outside the cell [illegible] cell membrane is much less than [illegible] an *electrochemical* event [illegible] side the cell, not to bulk [illegible]

EXERCISE **19.8** Neuron [illegible]

What would the membrane [illegible] were the only ion to be [illegible]

19.9 Common Batteri

Voltaic cells include the [illegible] ies. Some batteries, such as the [illegible] while others, such as [illegible] classified as primary or [illegible] and cathode can be easily [illegible] tions cannot easily be [illegible] "dead" and must be [illegible] a storage battery or a [illegible] can be reversed, so this [illegible]

Primary Batteries

For many years the "dry cell," [illegible] source of energy for [illegible] zinc, which acts as the anode. [illegible] liner of porous paper that [illegible] of the dry cell is a graphite [illegible] ture of ammonium chloride [illegible] oxide (MnO_2). As electrons [illegible]

$$Zn(s) \longrightarrow [illegible]$$

and the ammonium ions are [illegible]

$$2\,NH_4^+(aq) + 2\,e^- \longrightarrow [illegible]$$

The ammonia reacts with zinc [illegible]